IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of

HASHIZUME ET AL.

Serial No.: 10/606,182 Group Art Unit: 2861

Filed: June 26m 2003 Examiner: K. Feggins

For: INK JET RECORDING HEAD HAVING PIEZOELECTRIC ELEMENT AND ELECTRODE PATTERNED WITH SAME SHAPE AND WITHOUT PATTERN SHIFT THEREBETWEEN

DECLARATION UNDER 37 CFR 1.55(a)
(Pursuant to 37 CFR 1.68)

Honorable Commissioner of Patents and Trademarks
Alexandria, VA 22313-1450

Sir:

I, Toru Hatori, declare and state:

that I am a citizen of Japan, having an Office at P.O. Box 521, ARK Mori Building 13F, 12-32, Akasaka 1-chome, Minato-ku, Tokyo, 107 JAPAN;

that I well understand the Japanese and English languages;

that the attached English-language document is full, true and faithful translation made by me of Japanese Application No. Hei.

08-12113 filed on January 26, 1996, on which the right of priority under the International Convention is claimed for the above-identified application.

I declare further that all statements made herein of my own knowledge are true that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful statements may jeopardize the validity of the Application or any patent issuing thereon.

Date: May 11, 2005

Toru Hatori

[Title of the Invention]

INK JET PRINTER HEAD, INK JET PRINTER, INK JET PRINTER SYSTEM, AND METHOD FOR MANUFACTURING INK JET PRINTER HEAD

[Claims]

[Claim 1] In an ink jet printer head in which a substrate is formed with a plurality of grooves to provide ink flow passages, a diaphragm formed so as to cover said grooves, and a band-like piezoelectric thin film adherently formed on an opposite surface of said diaphragm to said grooves without overlapping a wall separating said plurality of grooves, said ink jet printer head is characterized in that said diaphragm is thinner in thickness in an area not adherently formed on said piezoelectric thin film than in an area adherently formed on said piezoelectric thin film.

[Claim 2] An ink jet printer head according to claim 1, characterized in that said diaphragm comprises a conductive film and insulating film for applying a voltage to said piezoelectric thin film, and as compared with a conductive film adherently formed on said piezoelectric thin film, a conductive film continued to said conductive film and not adherently formed on said piezoelectric thin film is thinner in thickness.

[Claim 3] An ink jet printer head according to claim 1, characterized in that said diaphragm comprises a conductive film for applying a voltage to said piezoelectric thin film.

[Claim 4] An ink jet printer head according to claim 1, characterized in that said diaphragm comprises a conductive film

and insulating film for driving said piezoelectric thin film, and a conductive film doubling as said diaphragm is adherently formed only on an area of said piezoelectric thin film in an area where said grooves are formed, and further that said conductive film doubling as said diaphragm is not formed on an insulating film doubling as said diaphragm in an area overlapping said grooves.

[Claim 5] An ink jet printer head according to claim 1, characterized in that said diaphragm comprises a conductive film and insulating film for driving said piezoelectric thin film, and said conductive film doubling as said diaphragm is adherently formed only on an area of said piezoelectric thin film in an area where said grooves are formed, and that said insulating film doubling as said diaphragm is thinner in thickness in an area where said piezoelectric thin film is not formed than in an area where said piezoelectric thin film is formed.

[Claim 6] An ink jet printer characterized by having said ink jet printer head according to any one of claims 1 to 5.

[Claim 7] An ink jet printer system characterized by having said ink jet printer head according to any one of claims 1 to 5.

[Claim 8] The method for manufacturing an ink jet printer head comprises the steps of: forming and attaching an insulating film onto a surface of a substrate; forming and attaching a first conductive film, forming and attaching a piezoelectric thin film onto said conductive film; forming and attaching a second conductive film onto said piezoelectric thin film; patterning a resist on said

second conductive film by photolithography; patterning said second conductive film and said piezoelectric thin film with said resist as a mask by a first etching method and a second etching method respectively, removing a part of said first conductive film, which is exposed by said patterning steps, by a third etching method such that a film thickness of said first conductive film is reduced; forming a plurality of grooves by an anisotropic method on a surface opposed to a surface of said piezoelectric thin film being formed.

[Claim 9] The method for manufacturing an ink jet printer head comprises the steps of: forming and attaching an insulating film onto a surface of a substrate; forming and attaching a first conductive film, forming and attaching a piezoelectric thin film onto said conductive film; forming and attaching a second conductive film onto said piezoelectric thin film; patterning a resist on said second conductive film by photolithography; patterning said second conductive film and said piezoelectric thin film with said resist as a mask by a first etching method and a second etching method respectively, removing a vibration area of said first conductive film, which is exposed by said patterning steps, by a third etching method; forming a plurality of grooves by an anisotropic method on a surface opposed to a surface of said piezoelectric thin film being formed.

[Claim 10] The method for manufacturing an ink jet printer head comprises the steps of forming and attaching an insulating film onto a surface of said substrate, forming and attaching a first

conductive film, forming and attaching a piezoelectric thin film onto said conductive film, and forming and attaching a second conductive film onto said piezoelectric thin film, and the steps of patterning a resist on said second conductive film by photolithography, patterning said second conductive film and said piezoelectric thin film with said resist as a mask by a first etching method, and removing an exposed diaphragm area of said first conductive film by a second etching method and consecutively etching an insulating film of the diaphragm area for making the insulating film thinner than the initial insulating film.

[Claim 11] The method for manufacturing an ink jet printer head as claimed in any one of claims 8 to 10 wherein said etching method includes irradiating the thin film with high-energy particles.

DETAILED DESCRIPTION OF THE INVENTION

[0001]

[Industrial Field of Utilization]

This invention relates to an ink jet printer head using a piezoelectric thin film for an ink jet drive source and a manufacturing method therefor. Further, it relates to an ink jet recorder using the recording head.

[0002]

[Prior Art]

There is a piezoelectric ink jet recording head using PZT elements comprising PZT of piezoelectric elements as electro-mechanical transducer elements of liquid or ink jet drive

source. The printer head conventionally consists of a head base formed with a multiplicity of separate ink passages, a diaphragm attached to the head base so as to cover all the separate ink passages, and a PZT element adherently formed in each portion on the diaphragm corresponding to the separate ink passage. Then, an electric field is applied to the PZT element for displacing the same, thereby pushing out ink in the separate ink passage from a nozzle of the separate ink passage.

[0003]

Prior art of the piezoelectric ink jet recording head is proposed in, for example, Japanese Patent Laid-Open No. Hei 5-286131. This prior art will be discussed with reference to Figure 31. The recording head has separate ink passages 102 on a head base 101 and a diaphragm 108 so as to cover the separate ink passages 102. A common electrode 105 is formed so that it is attached to the diaphragm 103, and PZT elements 104 are placed so as to reach the tops of the separate ink passages 102, a separate electrode 106 being placed on one face of the PZT element. An object of the invention in the conventional example is to provide an ink jet printer head and a manufacturing method therefor in which a step for cutting and bonding the PZT element is omitted, thus enabling simple and easy processing to a desired form by lithography, PZT can be mounted with high density and high accuracy, also a very thin PZT element can be formed, and further the PZT can be fired at low temperature.

[0004]

However, in Japanese Patent Laid-Open No. Hei 5-286131, no detailed description is given of a method for patterning the PZT element 104 and the electrode 106 applying a voltage.

[0005]

When formed by a screen printing method, the PZT element 104 and the electrode 106 become patterned thin films. However, the patterning method in screen printing has an accuracy problem despite the description of Japanese Patent Laid-Open No. Hei 5-286131, and the PZT element 104 and the electrode 106 can never be formed at the same position with accuracies of less than 2 μm. Otherwise, even if the PZT element 104 is patterned by screen printing to form a thin film and the electrode 106 is formed by photolithography after a film is formed by a sputtering method, since the PZT element 104 has already suffered a large shift in accuracy, exactly matched patterns cannot be provided.

[0006]

[Problems that the Invention is to Solve]

The conventional piezoelectric ink jet printer head structure as described above has the following problems.

[0007]

On the other hand, to jet ink equal to or more than ink with an ink jet using a bulk piezoelectric body for piezoelectric thin film of thin PZT element, it is desirable to form a PZT thin film having an extremely large piezoelectric constant more than bulk PZT for deforming a diaphragm. Generally, the piezoelectric constant

of the PZT thin film is only a half to a third of the piezoelectric constant of bulk PZT and if only PZT elements differ and other design values are the same, it is difficult to use the PZT thin film to jet ink more than ink with bulk PZT.

[0008]

A method of increasing the PZT thin film formation area is available to enable use of a PZT thin film having a small piezoelectric constant. According to this method, an amount of ink required for printing can be jetted, but if the PZT thin film area increases, ink jet printer head cannot be formed in high density and high-definition print quality cannot be provided.

[0009]

It is therefore an object of the invention to provide an ink jet recording head capable of effectively applying an electric field to a piezoelectric thin film and stably providing a sufficient jet characteristic with no pattern shift between the piezoelectric thin film and an electrode. It is another object of the invention to provide a high-definition, high-accuracy ink jet recording head while providing a sufficient ink jet amount in a small diaphragm area. It is a further object of the invention to provide a method for manufacturing the recording head. It is another object of the invention to provide an ink jet recorder and an ink jet printer system each comprising the recording head.

[0010]

[Means for Solving the Problem]

To achieve the object, the ink jet printer head of the invention has a structure characterized in that a head substrate is formed with a plurality of grooves to provide ink flow passages, a diaphragm which is formed so as to cover the grooves, and a band-like piezoelectric thin film adherently formed on a diaphragm surface opposite to the grooves without overlapping a wall separating the plurality of grooves, and that the diaphragm in the area not formed with the piezoelectric thin film is thinner in thickness than the diaphragm in the area formed with the piezoelectric thin film.

[0011]

Also, the ink jet printer head of the invention has a structure characterized in that a head substrate is formed with a plurality of grooves to provide ink flow passages, a diaphragm which is formed so as to cover the grooves and made of plural films of a conductive film and an insulating film, and a band-like piezoelectric thin film adherently formed on a diaphragm surface opposite to the grooves without overlapping a wall separating the plurality of grooves, and that a conductive film as the diaphragm in the area not adhered to the piezoelectric thin film is thinner in thickness than the diaphragm in the area adherently formed on the piezoelectric thin film.

[0012]

Also, the ink jet printer head of the invention has a structure characterized in that a head substrate is formed with a plurality

of grooves to provide ink flow passages, a diaphragm which is formed so as to cover the grooves and made of a conductive film, and a band-like piezoelectric thin film adherently formed on a diaphragm surface opposite to the grooves without overlapping a wall separating the plurality of grooves, and that a conductive film as the diaphragm in the area not adhered to the piezoelectric thin film is thinner in thickness than a diaphragm as the diaphragm in the area adherently formed on the piezoelectric thin film.

[0013]

Also, the ink jet printer head of the invention has a structure characterized in that a head substrate is formed with a plurality of grooves to provide ink flow passages, a diaphragm formed so as to cover the grooves, and a band-like piezoelectric thin film adherently formed on the diaphragm surface opposite to the grooves without overlapping a wall separating the plurality of grooves, and that the diaphragm is made of an insulating film and a conductive film, and a conductive film as the diaphragm is not formed in the area where the grooves are formed and the piezoelectric thin film is not formed.

[0014]

Also, the ink jet printer head of the invention has a structure characterized in that a head substrate is formed with a plurality of grooves to provide ink flow passages and with a band-like piezoelectric thin film in which a diaphragm formed so as to cover the grooves and made of a conductive film and insulating film for

driving the piezoelectric thin film is adherently formed on the diaphragm surface opposite to the grooves without overlapping a wall separating the plurality of grooves, and further that a conductive film doubling as the diaphragm is not formed on an insulating film doubling as a diaphragm in the area overlapping the grooves, and the insulating film doubling as the diaphragm is thinner in thickness in the area not overlapping the piezoelectric thin film than in the area overlapping the piezoelectric thin film.

[0015]

The ink jet printer of the invention is characterized by having the ink jet printer head described above.

[0016]

The ink jet printer system of the invention is characterized by having the ink jet printer head described above.

[0017]

The method for manufacturing an ink jet printer head according to the invention comprises the steps of: forming and attaching an insulating film onto a surface of a substrate; forming and attaching a first conductive film, forming and attaching a piezoelectric thin film onto said conductive film; forming and attaching a second conductive film onto said piezoelectric thin film; patterning a resist on said second conductive film by photolithography; patterning said second conductive film and said piezoelectric thin film with said resist as a mask by a first etching method and a second etching method respectively, removing a part of said first conductive film,

which is exposed by said patterning steps, by a third etching method such that a film thickness of said first conductive film is reduced; forming a plurality of grooves by an anisotropic method on a surface opposed to a surface of said piezoelectric thin film being formed.

[0018]

The method for manufacturing an ink jet printer head according to the invention comprises the steps of: forming and attaching an insulating film onto a surface of a substrate; forming and attaching a first conductive film, forming and attaching a piezoelectric thin film onto said conductive film; forming and attaching a second conductive film onto said piezoelectric thin film; patterning a resist on said second conductive film by photolithography; patterning said second conductive film and said piezoelectric thin film with said resist as a mask by a first etching method and a second etching method respectively, removing a vibration area of said first conductive film, which is exposed by said patterning steps, by a third etching method; forming a plurality of grooves by an anisotropic method on a surface opposed to a surface of said piezoelectric thin film being formed.

[0019]

The method for manufacturing an ink jet printer head according to the invention comprises the steps of forming and attaching an insulating film onto a surface of said substrate, forming and attaching a first conductive film, forming and attaching a piezoelectric thin film onto said conductive film, and forming and attaching a second

conductive film onto said piezoelectric thin film, and the steps of patterning a resist on said second conductive film by photolithography, patterning said second conductive film and said piezoelectric thin film with said resist as a mask by a first etching method, and removing an exposed diaphragm area of said first conductive film by a second etching method and consecutively etching an insulating film of the diaphragm area for making the insulating film thinner than the initial insulating film.

[0020]

In the methods for manufacturing an ink jet printer head, said first, second and third etching methods include irradiating the thin film with high-energy particles.

[0021]

[Preferred Embodiments]

Referring now to the accompanying drawings, there are shown preferred embodiments of the invention as will be discussed in details based on the figures.

[0022]

Figure 1 shows a sectional view of an ink jet recording head. Diaphragms VP and BE are formed and attached so as to cover a groove-like ink chamber IT separated by walls of a substrate SI. BE also serves as a common electrode of a piezoelectric thin film. The portion of the diaphragm-cum-electrode BE in the area not attached to the piezoelectric thin film and overlapping the ink chamber IT is thinner than the portion of the diaphragm-cum-electrode BE in the area attached

to the piezoelectric thin film. Piezoelectric thin film PZ patterned to a desired pattern is attached to the diaphragm-cum-electrode BE and an upper electrode UE is formed on an opposite face of the piezoelectric thin film with respect to the electrode BE. A nozzle plate NB is bonded to the wall face of the substrate SI on the opposite side with respect to the diaphragm VP, forming the ink chamber IT. The nozzle plate NB is formed with a nozzle orifice NH.

[0023]

When a voltage is applied to the piezoelectric thin film of the structure, the diaphragms VP and BE just above the ink chamber are deformed convexly on the ink chamber side. Ink as much as the volume difference between the ink chambers before and after the deformation is jetted through the nozzle orifice NH, thereby enabling printing.

[0024]

In the conventional ink jet head structure, the diaphragm thickness is the same in the area attached to the piezoelectric thin film and the area not attached to the piezoelectric thin film and overlapping the ink chamber IT, so that a large displacement is not provided and the amount of ink required for printing is not jetted. To attempt to obtain sufficient volume change in the ink chamber IT, the ink chamber needs to be lengthened remarkably. Resultantly, the head becomes a large area and very inconvenient to handle. However, the problems are solved at a stroke if the portion of the diaphragm in the area not attached to the piezoelectric thin

film and overlapping the ink chamber IT is thinner than the portion of the diaphragm in the area attached to the piezoelectric thin film as in the embodiment. That is, since the compliance of the diaphragm in area Lcb becomes large, if the same voltage is applied, the diaphragm warps larger than was previously possible, thereby providing larger ink chamber volume change than was previously possible.

[0025]

Further, since the PZT element and electrode positions shift for each element, the displacement amount varies greatly from one element to another, resulting in an ink jet printer head for jetting uneven amounts of ink.

[0026]

For example, in the structure in Figure 1, if the upper UE is made of Pt and is 100 nm thick, the piezoelectric thin film PZ is made of PZT having piezoelectric distortion constant d 31 of 100 pC/N and is 1000 nm thick, the width of the upper electrode UE and PZ, Wpz, is 40 μm, the diaphragm BE also serving as another electrode is made of Pt, the thickness of the area attached to the piezoelectric thin film, ta1 (Figure 1), 800 nm, the thickness of the area not attached to the piezoelectric thin film, ta2 (Figure 1), is 400 nm, and the diaphragm VP is made of a silicon oxide film and is 700 nm thick, when the voltage applied to the piezoelectric thin film PZ is 20 V, the maximum displacement amount of the diaphragm is 300 nm. On the other hand, if the thicknesses of the diaphragm

ta1 and ta2 are identical as 800 nm, when other conditions are the same, the maximum displacement amount of the diaphragm is 200 nm. Therefore, the embodiment enables a displacement to be provided 50% greater than was previously possible.

[0027]

An ink jet printer comprising the ink jet recording head of the embodiment jets ink in the amount 50% greater than was previously possible, thus can print clear images.

[0028]

A wordprocessor machine comprising the ink jet recording head of the embodiment jets ink or a computer system containing an ink jet printer comprising the ink jet recording head of the embodiment jets ink in the amount 50% greater than was previously possible, thus can print clear images.

[0029]

Figure 2 shows a sectional view of another ink jet recording head. A diaphragm BE is formed and attached so as to cover a groove-like ink chamber IT separated by walls of a substrate SI. The diaphragm BE also serves as an electrode of a piezoelectric thin film. The portion of the diaphragm-cum-electrode BE in the area not attached to the piezoelectric thin film and overlapping the ink chamber IT is thinner than the portion of the diaphragm-cum-electrode BE in the area attached to the piezoelectric thin film. Piezoelectric thin film PZ patterned to a desired pattern is attached to the diaphragm-cum-electrode BE and an upper electrode UE is formed on

an opposite face of the piezoelectric thin film with respect to the electrode BE. A nozzle plate NB is bonded to the wall face of the substrate SI on the opposite side with respect to the diaphragm BE, forming the ink chamber IT. The nozzle plate NB is formed with a nozzle orifice NH.

[0030]

When a voltage is applied to the piezoelectric thin film of this arrangement, the electrode BE just above the ink chamber is deformed convexly to the ink chamber side. As much ink as the volume difference in the ink chamber between before and after the deformation is jetted through the nozzle orifice NH, thereby enabling printing.

[0031]

In the conventional ink jet head structure, the diaphragm has the same thickness in the area adherently formed on the piezoelectric thin film and in the area on which the piezoelectric thin film is not adherently formed and which overlaps the ink chamber IT, so that a large displacement is not provided. Hence, there is a demerit that the amount of ink required for printing is not jetted. Also, to attempt to obtain a sufficient volume change in the ink chamber, the ink chamber needs to be considerably lengthened. Resultantly, there is a problem that the head becomes large in area and very inconvenient to handle. However, the above problems are solved at a stroke when the diaphragm is made thinner in thickness in the area on which the piezoelectric thin film is not adherently formed and which overlaps the ink chamber IT than in the area adherently

formed on the piezoelectric thin film as in the embodiment. Namely, since the compliance of the diaphragm in area Lcb becomes small, if the same voltage is applied, it becomes possible to obtain a larger ink chamber volume change than that in the conventional structure.

[0032]

The upper electrode UE is made of Pt and is 100 nm thick, the piezoelectric thin film PZ is made of PZT having piezoelectric distortion constant d 31 of 100 pC/N and is 1000 nm thick, the width of the upper electrode UE and PZ, Wpz, is 40 μm, the diaphragm BE also serving as another electrode is made of Pt, the thickness of the area attached to the piezoelectric thin film, tb1 (Figure 2), 800 nm, the thickness of the area not attached to the piezoelectric thin film, tb2 (Figure 2), is 400 nm, and the maximum displacement amount of the diaphragm is 400 nm. On the other hand, if the thicknesses of the diaphragm tb1 and tb2 are identical as 800 nm, when other conditions are the same, the maximum displacement amount of the diaphragm is 300 nm. Therefore, the embodiment enables a displacement to be provided 30% greater than was previously possible.

[0033]

In an ink jet printer having the ink jet printer head of the above embodiment, a jetted amount of ink is as much as 30% larger than in the conventional one, thus enabling printing of clear images.

[0034]

In a wordprocessor machine having the ink jet printer head

of the above embodiment, a jetted amount of ink is as much as 30% larger than in the conventional one, thus enabling printing of clear images.

[0035]

Figure 3 shows a sectional view of another ink jet recording head. A diaphragm VP is attached and formed so as to cover a groove-like ink chamber IT separated by walls of a substrate SI. An electrode BE is formed like a band on the diaphragm VP. The electrode BE also serves as a diaphragm. A piezoelectric thin film PZ patterned to a desired pattern is attached to the diaphragm-cum-electrode BE and an upper electrode UE is formed on an opposite face of the piezoelectric thin film with respect to the electrode BE. A nozzle plate NB is bonded to the wall face of the substrate SI on the opposite side with respect to the diaphragm BE, forming the ink chamber IT. The nozzle plate NB is formed with a nozzle orifice NH.

[0036]

When a voltage is applied to the piezoelectric thin film of this arrangement, the electrode BE just above the ink chamber is deformed convexly to the ink chamber side. As much ink as the volume difference in the ink chamber between before and after the deformation is jetted through the nozzle orifice NH, thereby enabling printing.

[0037]

In the conventional ink jet head structure, the diaphragm has the same thickness in the area adherently formed on the piezoelectric thin film and in the area on which the piezoelectric

thin film is not adherently formed and which overlaps the ink chamber IT, so that a large displacement is not provided. Hence, there is a demerit that the amount of ink required for printing is not jetted. Also, to attempt to obtain a sufficient volume change in the ink chamber, the ink chamber needs to be considerably lengthened. Resultantly, there is a problem that the head becomes large in area and very inconvenient to handle. However, the above problems are solved at a stroke when the diaphragm is made thinner in thickness in the area on which the piezoelectric thin film is not adherently formed and which overlaps the ink chamber IT than in the area adherently formed on the piezoelectric thin film as in the embodiment. Namely, since the compliance of the diaphragm in area Lcb becomes small, if the same voltage is applied, it becomes possible to obtain a larger ink chamber volume change than that in the conventional structure.

[0038]

For example, the upper electrode UE is made of Pt and is 100 nm thick, the piezoelectric thin film PZ is made of PZT having piezoelectric distortion constant d 31 of 100 pC/N and is 1000 nm thick, the width of the upper electrode UE and PZ, Wpz, is 40 μm, the diaphragm BE also serving as another electrode is made of Pt, the thickness of the area attached to the piezoelectric thin film, tc1 (Figure 3), 800 nm, the thickness of the area not attached to the piezoelectric thin film, tc2 (Figure 3), is 400 nm, and the maximum displacement amount of the diaphragm is 400 nm. On the other

hand, if the thicknesses of the diaphragm tc1 and tc2 are identical as 800 nm, when other conditions are the same, the maximum displacement amount of the diaphragm is 300 nm. Therefore, the embodiment enables a displacement to be provided 30% greater than was previously possible.

[0039]

In an ink jet printer having the ink jet printer head of the above embodiment, a jetted amount of ink is as much as 30% larger than in the conventional one, thus enabling printing of clear images.

[0040]

In a wordprocessor machine having the ink jet printer head of the above embodiment, a jetted amount of ink is as much as 30% larger than in the conventional one, thus enabling printing of clear images.

[0041]

Figure 4 shows a sectional view of another ink jet recording head. A diaphragm VP is attached and formed so as to cover a groove-like ink chamber IT separated by walls of a substrate SI. An electrode BE is formed like a band on the diaphragm VP. The electrode BE also serves as a diaphragm. The portion of the diaphragm VP in the area not attached to a piezoelectric thin film and overlapping the ink chamber IT is thinner than the portion of the diaphragm VP in the area attached to the piezoelectric thin film. Piezoelectric thin film PZ patterned to a desired pattern is attached to the diaphragm-cum-electrode BE and an upper electrode UE is formed on an opposite face of the piezoelectric thin film with respect to

the electrode BE. A nozzle plate NB is bonded to the wall face of the substrate SI on the opposite side with respect to the diaphragm BE, forming the ink chamber IT. The nozzle plate NB is formed with a nozzle orifice NH.

[0042]

When a voltage is applied to the piezoelectric thin film of this arrangement, the electrode BE just above the ink chamber is deformed convexly to the ink chamber side. As much ink as the volume difference in the ink chamber between before and after the deformation is jetted through the nozzle orifice NH, thereby enabling printing.

[0043]

In the conventional ink jet head structure, the diaphragm has the same thickness in the area adherently formed on the piezoelectric thin film and in the area on which the piezoelectric thin film is not adherently formed and which overlaps the ink chamber IT, so that a large displacement is not provided. Hence, there is a demerit that the amount of ink required for printing is not jetted. Also, to attempt to obtain a sufficient volume change in the ink chamber, the ink chamber needs to be considerably lengthened. Resultantly, there is a problem that the head becomes large in area and very inconvenient to handle. However, the above problems are solved at a stroke when the diaphragm is made thinner in thickness in the area on which the piezoelectric thin film is not adherently formed and which overlaps the ink chamber IT than in the area adherently formed on the piezoelectric thin film as in the embodiment. Namely,

since the compliance of the diaphragm in area Lcb becomes small, if the same voltage is applied, it becomes possible to obtain a larger ink chamber volume change than that in the conventional structure.

[0044]

For example, the upper electrode UE is made of Pt and is 100 nm thick, the piezoelectric thin film PZ is made of PZT having piezoelectric distortion constant d 31 of 100 pC/N and is 1000 nm thick, the width of the upper electrode UE and PZ, Wpz, is 40 μm, the diaphragm BE also serving as another electrode is made of Pt, the thickness of the area attached to the piezoelectric thin film, td1 (Figure 4), 800 nm, the thickness of the area not attached to the piezoelectric thin film, td2 (Figure 4), is 400 nm, and the maximum displacement amount of the diaphragm is 400 nm. On the other hand, if the thicknesses of the diaphragm td1 and td2 are identical as 800 nm, when other conditions are the same, the maximum displacement amount of the diaphragm is 300 nm. Therefore, the embodiment enables a displacement to be provided 30% greater than was previously possible.

[0045]

In an ink jet printer having the ink jet printer head of the above embodiment, a jetted amount of ink is as much as 30% larger than in the conventional one, thus enabling printing of clear images.

[0046]

In a wordprocessor machine having the ink jet printer head of the above embodiment, a jetted amount of ink is as much as 30%

larger than in the conventional one, thus enabling printing of clear images.

[0047]

As shown in Figure 6, an insulating film SD is formed on both faces of a substrate SI as shown in Figure 5. Next, as shown in Figure 7, a diaphragm-cum-electrode BE of a conductive film is formed and attached onto the insulating film SD on one face of the substrate SI.

Next, as shown in Figure 8, a piezoelectric thin film PZ is formed and attached onto the diaphragm-cum-electrode BE of a conductive film. As shown in Figure 9, an upper electrode UE is formed and attached onto the piezoelectric thin film PZ. As shown in Figure 10, a patterned mask material RS is formed and attached onto the insulating film SD on the surface of the substrate SI where the piezoelectric thin film PZ is not formed.

Next, as shown in Figure 11, the insulating film SD is etched out according to the mask RS, forming patterned insulating films ESD. As shown in Figure 12, the mask material RS is stripped off. Next, as shown in Figure 13, a mask material RSD is formed and attached onto the upper electrode UE so as to prepare an area not overlapping the patterned insulating films ESD. As shown in Figure 14, the etched upper electrode EUE is patterned according to the mask material RSD by a first etching method.

Next, as shown in Figure 15, the piezoelectric thin film PZ is patterned according to the mask material RSD by a second etching

method. As shown in Figure 16, the diaphragm-cum-electrode BE of the first conductive film having thickness tz1 is etched out from the surface as thick as tz3 so that thickness tz2 is left by a third etching method.

Next, as shown in Figure 17, the mask material RSD is stripped off. As shown in Figure 18, the substrate SI is etched out with the etched insulating films ESD as a mask, forming a groove CV.

Further, as shown in Figure 19, a nozzle plate NB formed with a nozzle orifice NH is bonded so as to come in contact with the etched insulating films ESD for forming an ink chamber IT, thereby manufacturing an ink jet printer head substrate.

[0048]

To match the upper electrode UE, the piezoelectric thin film PZ, and the diaphragm-cum-electrode BE of the conductive film in patterning, the etching method may be an etching method for irradiating with particles accelerated to high energy by an electric field or an electromagnetic field and enabling etching independently of the material.

[0049]

As shown in Figure 5, the monocrystalline silicon substrate SI cleaned in a 60% nitric acid solution at 100°C for 30 minutes or more for cleaning the substrates is prepared. The plane orientation of the monocrystalline silicon substrate is <110>. It is not limited to <110> and may be adopted in response to the ink supply passage formation pattern.

[0050]

Next, as shown in Figure 6, the insulating films SD are formed on the surfaces of the monocrystalline silicon substrate SI. Specifically, the monocrystalline silicon substrate SI is inserted into a thermal oxidation furnace and oxygen having a purity of 99.999% or more is introduced into the thermal oxidation furnace, then a silicon oxide film 1 μm thick is formed at temperature 1100°C for five hours. The thermal oxide film formation method is not limited to it and the thermal oxide film may be, for example, a silicon oxide film formed by wet oxidation or a silicon oxide film formed by a reduced pressure chemical vapor phase growth method, an atmospheric pressure chemical vapor phase growth method, or an electron cyclotron resonance chemical vapor phase growth method.

[0051]

Next, as shown in Figure 7, the electrode BE of a piezoelectric thin film also serving as a diaphragm of an ink jet printer head is formed and attached onto the silicon oxide film SD formed on one face of the monocrystalline silicon substrate SI. The electrode BE formation method may be a sputtering method, an evaporation method, an organic metal chemical vapor phase growth method, or a plating method. The electrode BE may be made of a conductive substance having mechanical resistance as a diaphragm of an actuator.

[0052]

A formation method of a platinum electrode BE 800 nm thick by the sputtering method will be discussed. Using a single wafer

processing sputtering system provided with a load lock chamber, a silicon substrate formed on the surfaces with a silicon oxide films at initial vacuum degree 10^{-7} torr or less is introduced into a reaction chamber and a platinum thin film 800 nm thick is formed and attached onto the silicon oxide films under the conditions of pressure 0.6 Pa, sputtering gas Ar flow quantity 50 sccm, substrate temperature 250°C, output 1 kW, and time 20 minutes. Since the platinum thin film on the silicon oxide film is remarkably inferior in intimate contact property to metal films of Al, Cr, etc., rich in reactivity, a titania thin film several nm to several ten nm thick is formed between the silicon oxide film and the platinum thin film for providing a sufficient intimate contact force.

[0053]

Next, as shown in Figure 8, the piezoelectric thin film PZ is formed and attached onto the electrode BE. The piezoelectric thin film PZ is made of lead zirconate titanate or lead zirconate titanate doped with impurities; in the invention, it may be made of either of them.

[0054]

In the piezoelectric thin film formation method, a film of an organic metal solution containing lead, titanium, and zirconium in sol state is formed by a spin coating method and calcined and hardened by a rapid thermal annealing method, forming the piezoelectric thin film PZ in ceramic state. The piezoelectric thin film PZ is about 1 μm thick. In addition, a sputtering method is available

as the manufacturing method of the piezoelectric thin film PZ of lead zirconate titanate.

[0055]

Next, as shown in Figure 9, the upper electrode UE for applying a voltage to the piezoelectric thin film is formed and attached onto the piezoelectric thin film PZ. The upper electrode UE is made of a conductive film, preferably a metal thin film such as a platinum thin film, an aluminum thin film, an aluminum thin film doped with impurities of silicon and copper, or a chromium thin film. Here, particularly a platinum thin film is used. The platinum thin film is formed by the sputtering method. It is 100 nm to 200 nm thick. An aluminum thin film having a small young's modulus can be used in addition to the aluminum thin film.

[0056]

Next, as shown in Figure 10, the resist thin film patterned like an ink supply passage by photolithography, RS, is formed and attached onto the silicon oxide film SD on the surface of the monocrystalline silicon substrate SI where the piezoelectric thin film PZ is not formed.

[0057]

Next, as shown in Figure 11, the silicon oxide film SD in the area not covered with the resist thin films RS is etched out. In the invention, the etching method may be a wet etching method using hydrofluoric acid or a mixed solution of hydrofluoric acid and ammonium or a dry etching method using radicalized freon gas

as an etchant.

[0058]

Next, as shown in Figure 12, the resist thin film RS as the mask material is stripped off by immersing the silicon substrate formed with the piezoelectric thin film in an organic solvent containing phenol and heating at 90°C for 30 minutes. Alternatively, the resist thin film RS can also be removed easily by a high-frequency plasma generator using oxygen for reactive gas.

[0059]

Next, as shown in Figure 13, the second resist thin film RSD patterned by photolithography is formed and attached onto the upper electrode UE so that it becomes an area overlapping and narrower than the silicon oxide film removal area of the monocrystalline silicon substrate SI.

[0060]

Next, as shown in Figure 14, the upper electrode UE is etched out with the resist thin film RSD as a mask for forming the patterned electrode EUE. If the upper electrode UE is made of a platinum thin film, the etching method is a so-called ion milling method by which the platinum thin film is irradiated with argon ions of high energy 500-800 eV.

[0061]

Next, as shown in Figure 15, subsequent to the etching of the upper electrode UE, the piezoelectric thin film PZ is etched with the resist thin film RSD left. The etching method is a so-called

ion milling method by which the piezoelectric thin film is irradiated with argon ions of high energy 500-800 eV.

[0062]

As shown in Figure 16, the electrode BE is etched with the resist thin film RSD left. It is not etched over all the film thickness and is etched out by the thickness tz3, namely, as thick as 400 nm, as shown in Figure 16. The etching method is a so-called ion milling method by which the piezoelectric thin film is irradiated with argon ions of high energy 500-800 eV.

[0063]

As in the embodiment, the upper electrode UE, the piezoelectric thin film PZ, and the electrode BE are consecutively irradiated with argon ions having high energy for anisotropic etching, whereby the upper electrode UE and the piezoelectric thin film PZ are patterned according to the resist thin film RSD of the same mask material, thus resulting in a pattern matching within 1 μm of shift. The shift between the piezoelectric thin film PZ pattern and the unetched area of the electrode BE also becomes within 1 μm.

[0064]

This etching etches not only the etched films, but also the resist thin film of the mask material. The resist thin film etching rate ratio between platinum and novolac resin family by irradiation with argon ions of high energy is 2:1 and the resist etching rate ratio between lead zirconate titanate and novolac resin family by irradiation with argon ions of high energy is 1:1. Thus, the resist

RSD film of the mask material is made 1.8-2.5 μm thick.

[0065]

Next, as shown in Figure 17, the resist thin film RSD is dissolved and removed in a phenol family organic solvent or is removed by a high-frequency plasma etching system using oxygen gas.

[0066]

Next, as shown in Figure 18, the silicon surface exposure area of the monocrystalline silicon substrate SI where the piezoelectric thin film is not formed is etched for forming the groove CV. For this etching, the silicon substrate is immersed in a 5%-40% potassium hydroxide aqueous solution at 80°C for 80 minutes to three hours and silicon is etched until the silicon oxide film SD on the side of the monocrystalline silicon substrate SI where the piezoelectric thin film is formed is exposed. When the silicon etching is executed, the silicon substrate surface on the piezoelectric thin film side may be formed with a protective film or a partition wall for protecting against the etching solution so that the piezoelectric thin film does not come in contact with the etching solution.

[0067]

When the plane orientation of the monocrystalline silicon substrate is <110>, if the wall faces defining the groove CV are designed so that <111> plane appears, the etching rate of the <111> plate of monocrystalline silicon to a potassium hydroxide aqueous solution is 1/100-1/200 of that of the <110> plane, thus the walls

of the groove CV are formed almost perpendicularly to the device formation face of the monocrystalline silicon substrate.

[0068]

Next, as shown in Figure 19, the nozzle plate NB 0.1-1 mm thick is bonded to the surface of the silicon oxide film SD so as to cover the groove CV formed by the etching, forming the ink chamber tank IT. The nozzle plate NB is made of a material having a high young's modulus and high rigidity, such as a stainless, copper, plastic, or silicon substrate. It is bonded in an adhesive or by an electrostatic force between the silicon oxide film SD and plate. The nozzle plate NB is formed with the nozzle orifice NH for jetting ink chamber in the groove CV to the outside by the diaphragm-cum-electrode BE vibrated by drive of the piezoelectric thin film PZ.

[0069]

In the embodiment, the same steps as those previously described with reference to Figs. 5 to 18 are executed.

[0070]

As shown in Figure 20, following the step in Figure 18, the silicon oxide film whose surface is exposed with silicon etched out is etched out in a hydrofluoric acid aqueous solution or a mixed solution of hydrofluoric acid and ammonium fluoride, exposing the surface of the diaphragm-cum-electrode BE.

[0071]

The silicon oxide film etching method may be a dry etching

method for irradiating with plasma generated at high frequencies as well as the wet etching.

[0072]

Next, as shown in Fig. 21, the nozzle plate NB 0.1-1 mm thick is bonded to the surface of the silicon oxide film SD so as to cover the groove CV formed by the etching, forming the ink chamber IT. The nozzle plate NB is made of a material having a high young's modulus and high rigidity, such as a stainless, copper, plastic, or silicon substrate. It is bonded in an adhesive or by an electrostatic force between the silicon oxide film SD and plate. The nozzle plate NB is formed with the nozzle orifice NH for jetting ink in the ink chamber IT to the outside by the diaphragm-cum-electrode BE vibrated by drive of the piezoelectric thin film PZ.

[0073]

In the embodiment, the same steps as those previously described with reference to Figures 5 to 15 are executed.

[0074]

As shown in Figure 22, following the step in Figure 15, the diaphragm-cum-electrode BE of the first conductive film is etched out according to the mask material RSD. Next, as shown in Figure 23, the mask material RSD is stripped off. Next, as shown in Figure 24, the substrate SI is etched out with the patterned insulating films ESD as a mask, forming the groove CV.

Next, as shown in Figure 25, the nozzle plate NB is bonded to the patterned insulating films ESD so as to cover the groove

CV for forming the ink chamber IT, thereby manufacturing the ink jet recording head substrate.

[0075]

To match the upper electrode UE, the piezoelectric thin film PZ, and the diaphragm-cum-electrode BE of the conductive film in a pattern, the first, second, and third etching methods may be an etching method for irradiating with particles highly energized by an electric field or an electromagnetic field and enabling etching independently of the material.

[0076]

In the embodiment, the same steps as those previously described with reference to Figs. 5 to 15 are executed.

[0077]

As shown in Figure 22, following the step in Figure 15, the diaphragm-cum-electrode BE is etched out with the resist thin film RSD as a mask. The etching method is a so-called ion milling method by which the diaphragm-cum-electrode BE is irradiated with argon ions of high energy 500-800 eV. In addition, the diaphragm-cum-electrode BE can also be etched out if dry etching is executed whereby BE is irradiated with anisotropic high energy particles.

[0078]

As in the embodiment, the upper electrode UE, the piezoelectric thin film PZ, and the electrode BE are consecutively irradiated with argon ions having high energy for anisotropic etching, whereby

the upper electrode UE and the piezoelectric thin film PZ are patterned according to the resist thin film RSD of the same mask material, thus providing the patterns matching each other with a shift of less than 1 µm. Further, the piezoelectric thin film PZ and the electrode BE are also patterned according to the resist thin film RSD of the same mask material, thus providing the patterns matching each other with a shift of less than 1 µm.

[0079]

As in the embodiment, the upper electrode UE, the piezoelectric thin film PZ, and the electrode BE are consecutively irradiated with argon ions having high energy for etching, thereby etching not only the etched film but also the resist thin film of the mask material. The resist thin film etching rate ratio between platinum and novolac resin family by irradiation with argon ions of high energy is 2:1, while the resist etching rate ratio between lead zirconate titanate and novolac resin family is 1:1. Thus, the resist RSD film of the mask material is 2 to 3 µm thick.

[0080]

Next, as shown in Figure 23, the resist thin film RSD is dissolved and removed in a phenol family organic solvent or is removed by a high-frequency plasma etching system using oxygen gas.

[0081]

Next, as shown in Fig. 24, the silicon surface exposure area on the monocrystalline silicon substrate SI surface on the side where the piezoelectric thin film is not formed is etched for forming

the groove CV. For this etching, the silicon substrate is immersed in a 10 to 40% potassium hydroxide aqueous solution at 80°C for 2 to 3 hours, and silicon is etched out so as to expose the silicon oxide film SD on the side of the monocrystalline silicon substrate SI where the piezoelectric thin film is formed. When the silicon etching is executed, the silicon substrate surface on the piezoelectric thin film side may be formed with a protective film or a partition wall for protecting against the etching solution so that the piezoelectric thin film does not come in contact with the etching solution.

[0082]

Next, as shown in Fig. 25, the nozzle plate NB 0.1 to 1 mm thick is bonded to the surface of the silicon oxide film SD so as to cover the groove CV formed by the above etching, thus forming the ink chamber IT. The nozzle plate NB is made of a material having a high young's modulus and high rigidity, such as a stainless, copper, plastic, or silicon substrate. Also, it is bonded by use of an adhesive or by an electrostatic force between the silicon oxide film SD and plate. The nozzle plate NB is formed with the nozzle orifice NH for jetting ink pooled in the groove CV to the outside by the diaphragm-cum-electrode BE being vibrated by drive of the piezoelectric thin film PZ.

[0083]

In the embodiment, the same steps as those previously described with reference to Figs. 5 to 15 are executed.

[0084]

Next, as shown in Fig. 26, following the step in Fig. 15, the diaphragm-cum-electrode BE of the first conductive film is etched out with the resist thin film RSD as a mask. Then, as shown in Fig. 27, the insulating film VP having thickness td1 is etched out by thickness td3 from the surface so that thickness td2 is left according to the mask material RSD. Next, as shown in Fig. 28, the mask material RSD is stripped off. Then, as shown in Fig. 29, the substrate SI is etched out with the etched insulating films ESD as a mask material, thus forming the groove CV. Further, as shown in Fig. 30, the nozzle plate NB formed with the nozzle orifice NH is bonded so as to come into contact with the etched insulating films ESD for forming the ink chamber IT, thereby manufacturing the ink jet printer head substrate.

[0085]

To match the upper electrode UE, the piezoelectric thin film PZ, and the diaphragm-cum-electrode BE of the conductive film in a pattern, the first, second, and third etching methods may be an etching method for irradiating with particles accelerated to high energy by an electric field or an electromagnetic field and enabling etching independently of the material.

[0086]

In the embodiment, the same steps as those previously described with reference to Figs. 5 to 15 are executed.

[0087]

Next, as shown in Fig. 26, following the step in Fig. 15, the diaphragm-cum-electrode BE is etched out with the resist thin film RSD as a mask. The etching method is a so-called ion milling method by which the diaphragm-cum-electrode BE is irradiated with argon ions of high energy 500 to 800 eV. In addition, the diaphragm-cum-electrode BE can also be etched out if dry etching is executed by irradiation with anisotropic high energy particles.

[0088]

Next, as shown in Fig. 27, the diaphragm VP 500 nm as thick as td3 is etched out so that thickness td2 out of the diaphragm VP having thickness td1 is left with the resist thin film RSD as a mask. The etching method is a so-called ion milling method by which the diaphragm VP is irradiated with argon ions of high energy 500 to 800 eV. In addition, the diaphragm VP can also be etched out if dry etching is executed by irradiation with anisotropic high energy particles.

[0089]

As in the embodiment, the upper electrode UE, the piezoelectric thin film PZ, and the electrode BE are consecutively irradiated with argon ions having high energy for anisotropic etching, whereby the upper electrode UE and the piezoelectric thin film PZ are patterned according to the resist thin film RSD of the same mask material, thus providing the patterns matching each other with a shift of less than 1 μm. The piezoelectric thin film PZ and the electrode BE are also patterned according to the resist thin film RSD of the

same mask material, thus providing the patterns matching each other with a shift of less than 1 μm. Further, the shift between the piezoelectric thin film PZ pattern and the unetched area of the electrode BE also falls within 1 μm.

[0090]

As in the embodiment, the upper electrode UE, the piezoelectric thin film PZ, and the electrode BE are consecutively irradiated with argon ions having high energy for etching, thereby etching not only the etched film but also the resist thin film of the mask material. The resist thin film etching rate ratio between platinum and novolac resin family by irradiation with argon ions of high energy is 2:1, while the resist etching rate ratio between lead zirconate titanate and novolac resin family is 1:1. Thus, the resist RSD film of the mask material is 2.5 to 3.5 μm thick.

[0091]

Next, as shown in Fig. 28, the resist thin film RSD is dissolved and removed in a phenol family organic solvent or is removed by a high-frequency plasma etching system using oxygen gas.

[0092]

Next, after the resist thin film RSD is removed, as shown in Fig. 29, the silicon surface exposure area on the monocrystalline silicon substrate SI surface on the side where the piezoelectric thin film is not formed is etched for forming the groove CV. For this etching, the silicon substrate is immersed in a 10 to 40% potassium hydroxide aqueous solution at 80°C for 2 to 3 hours, and silicon

is etched out so as to expose the silicon oxide film SD on the side of the monocrystalline silicon substrate SI where the piezoelectric thin film is formed. When the silicon etching is executed, the silicon substrate surface on the piezoelectric thin film side may be formed with a protective film or a partition wall for protecting against the etching solution so that the piezoelectric thin film does not come in contact with the etching solution.

[0093]

Next, as shown in Fig. 30, the nozzle plate NB 0.1 to 1 mm thick is bonded to the surface of the silicon oxide film SD so as to cover the groove CV formed by the above etching, thus forming the ink chamber IT. The nozzle plate NB is made of a material having a high young's modulus and high rigidity, such as a stainless, copper, plastic, or silicon substrate. Also, it is bonded by use of an adhesive or by an electrostatic force between the silicon oxide film SD and plate. The nozzle plate NB is formed with the nozzle orifice NH for jetting ink pooled in the groove CV to the outside by the diaphragm-cum-electrode BE being vibrated by drive of the piezoelectric thin film PZ.

[0094]

[Effects of the Invention]

As we have discussed, since the structure of the ink jet printer head provides a drastically large vibration capability of the diaphragm of an active element for jetting ink as compared with conventional structures, the following effects can be produced:

[0095]

(1) Since the diaphragm has a large vibration amount, the volume displacement of the ink holding chamber increases. Therefore, a larger amount of ink than was previously possible can be jetted, so that an ink jet printer for realizing clearer print quality can be provided.

[0096]

(2) Since the diaphragm has a large vibration amount, the volume displacement of the ink holding chamber per unit volume increases. Therefore, if the ink jet amount is the same as the previous amount, an ink holding room of a volume smaller than the conventional ink holding room may be installed, so that the ink jet recording head becomes smaller in size than was previously possible. Thus, a more compact ink jet recorder can be provided.

[0097]

(3) Since the diaphragm has a large vibration amount, if the piezoelectric thin film has a smaller displacement capability than was previously possible, an ink jet recording head can be provided. Thus, the piezoelectric thin film may be several µm thick, so that the need for using a bulk piezoelectric thin film is eliminated; films can be formed by a spinner and piezoelectric elements can be easily formed by the sputtering method. Thus, ink jet recording heads can be manufactured in a thin-film process enabling high-volume manufacturing, so that inexpensive and high-quality ink jet recording heads can be provided.

[0098]

(4) Since the etching method for irradiating with high-energy particles is used for patterning, the etching patterns of the piezoelectrice thin film, the electrode for applying a voltage, and compliance increase match with extremely high accuracy, so that the capacity does not vary from one element to another. Thus, ink jet recording heads extremely high in print quality uniformity can be provided.

BRIEF DESCRIPTION OF THE DRAWING

In the accompanying drawings:

Figure 1 is a sectional view of an ink jet recording head of the invention;

Figure 2 is a sectional view of an ink jet recording head of the invention;

Figure 3 is a sectional view of an ink jet recording head of the invention;

Figure 4 is a sectional view of an ink jet recording head of the invention;

Figure 5 is a sectional view of a step of a manufacturing method of the ink jet recording head of the invention;

Figure 6 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 7 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 8 is a sectional view of a step of the manufacturing

method of the ink jet recording head of the invention;

Figure 9 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 10 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 11 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 12 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 13 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 14 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 15 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 16 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 17 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 18 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 19 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 20 is a sectional view of a step of a manufacturing method of the ink jet recording head of the invention;

Figure 21 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 22 is a sectional view of a step of a manufacturing method of the ink jet recording head of the invention;

Figure 23 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 24 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 25 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 26 is a sectional view of a step of a manufacturing method of the ink jet recording head of the invention;

Figure 27 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 28 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 29 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention;

Figure 30 is a sectional view of a step of the manufacturing method of the ink jet recording head of the invention; and

Figure 31 is a sectional view to show a conventional example.

[Explanation of Reference Numerals]

1: Head base

2: Silicon thermal oxide film

3: Common electrode

4: Piezoelectric thin film

5: Upper electrode

6: Nega resist

7: Hardened nega resist

8: Diaphragm

9: Ink pressure chamber

10: Nozzle plate

BE: Diaphragm-cum-electrode

CV: Groove

ESD: Patterned insulating film

EUE: Etched upper electrode

IT: Ink chamber

NB: Nozzle plate

NH: Nozzle orifice

PZ: Piezoelectric thin film

RS: Mask

RSD: Mask material

SD: Insulating film

SI: Substrate

UE: Upper electrode

101: Head base

102: Separate ink passage

103: Diaphragm

104: PZT element

105: Common electrode

106: Separate electrode

VP: Diaphragm

ABSTRACT OF THE DISCLOSURE

[Problem]

A performance ink-jet printer head and the method thereof are provided by the actuator having an enough displacement of the piezoelectric device.

[Solution Means]

The diaphragm BE is partly overlapped with the ink chamber IT at a vicinity of the area of the piezoelectric thin film being formed, the thickness of said overlapped area ta2 is formed thinner than thickness ta1 of the area being attached to the piezoelectric thin film, which is formed by the dry-etching method.

【書類名】 図面

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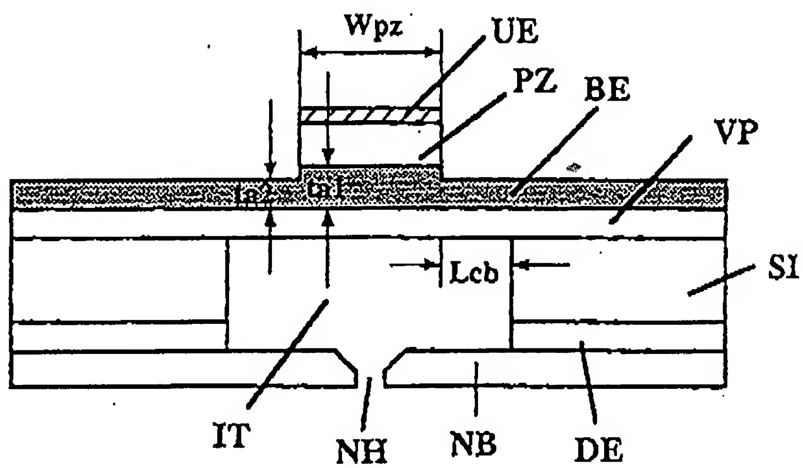

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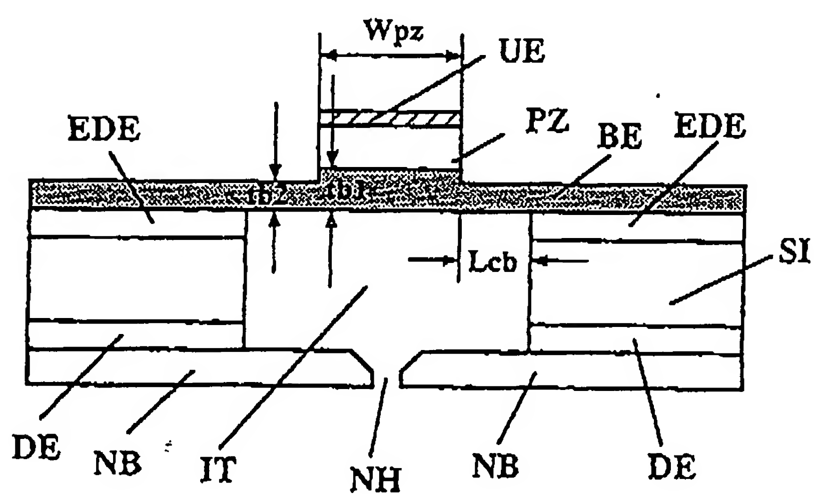

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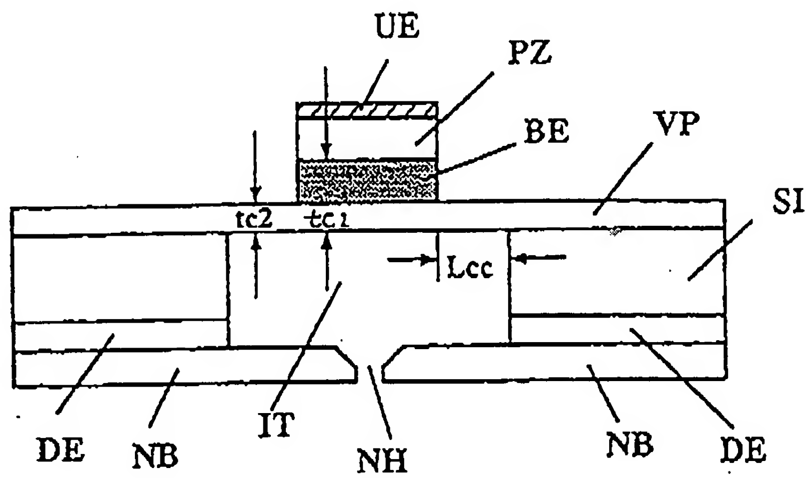
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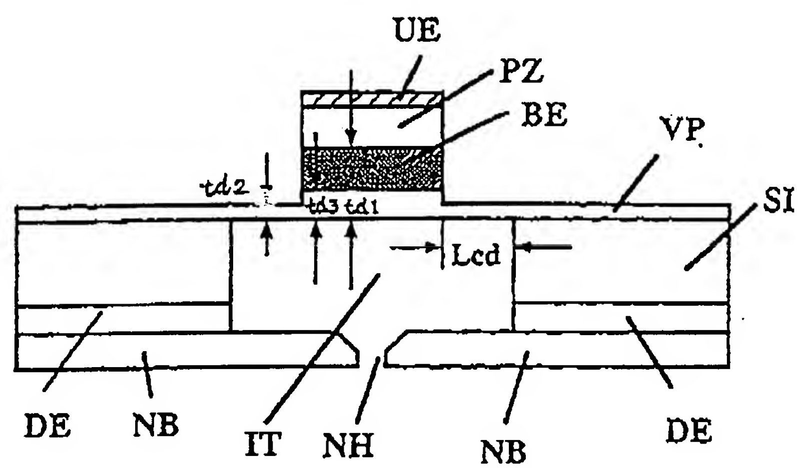
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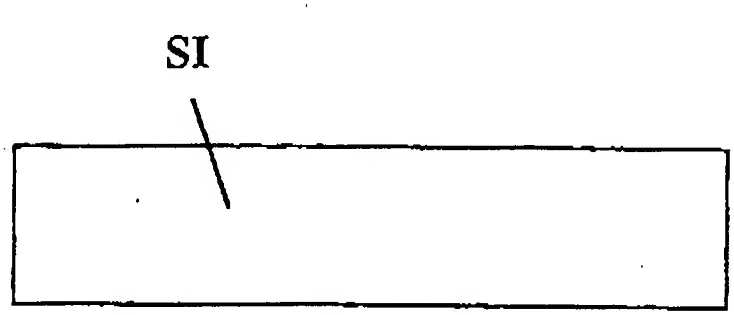
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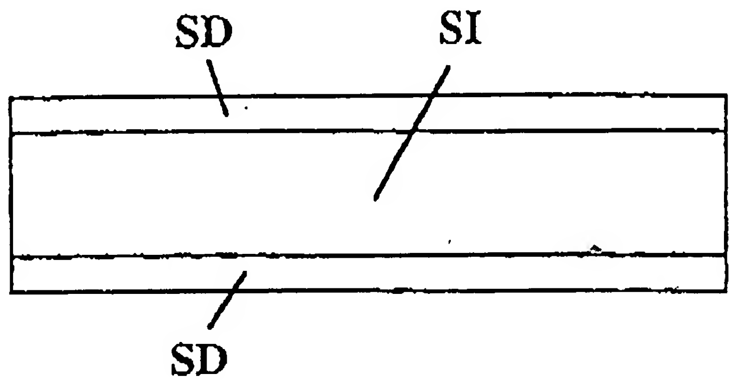

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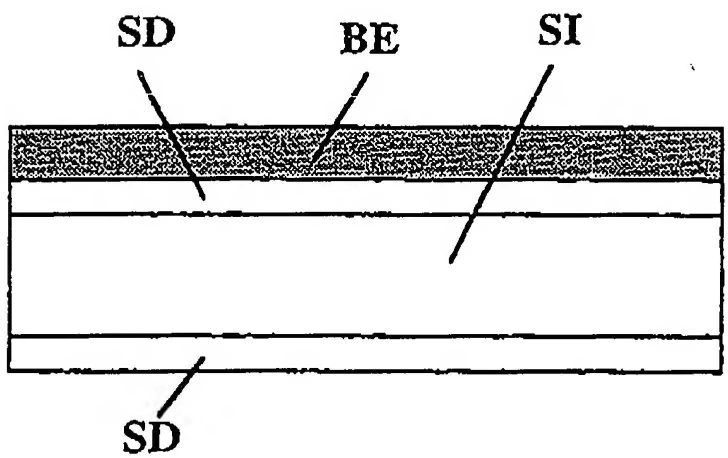

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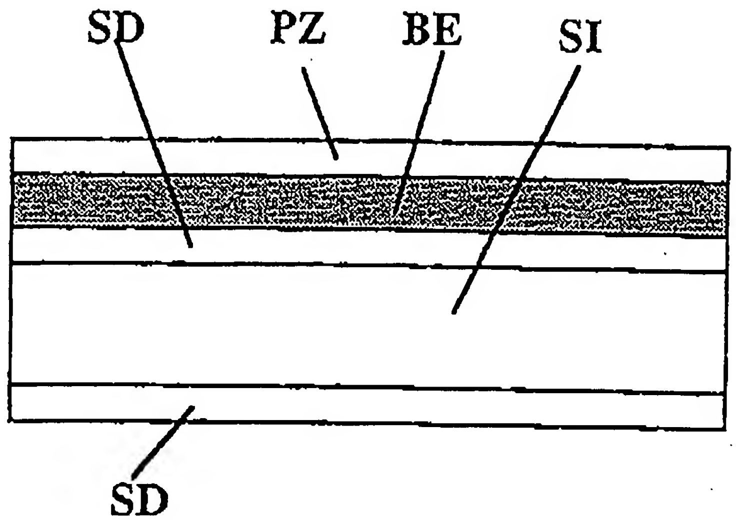

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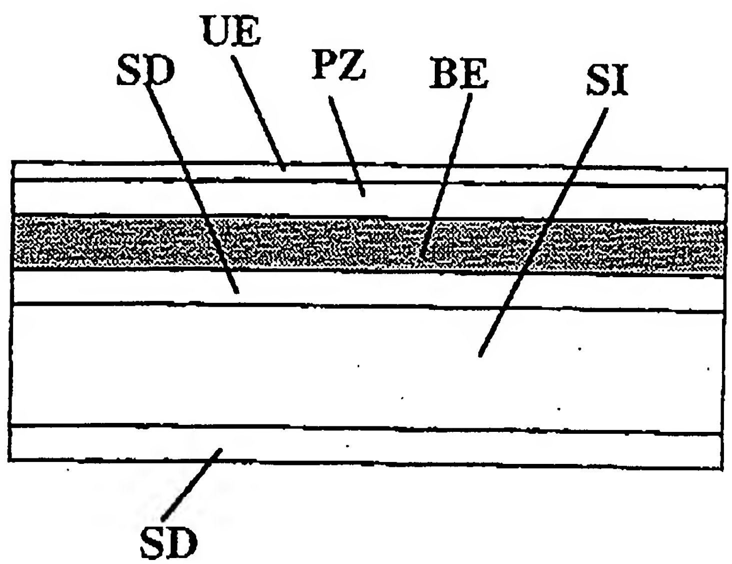

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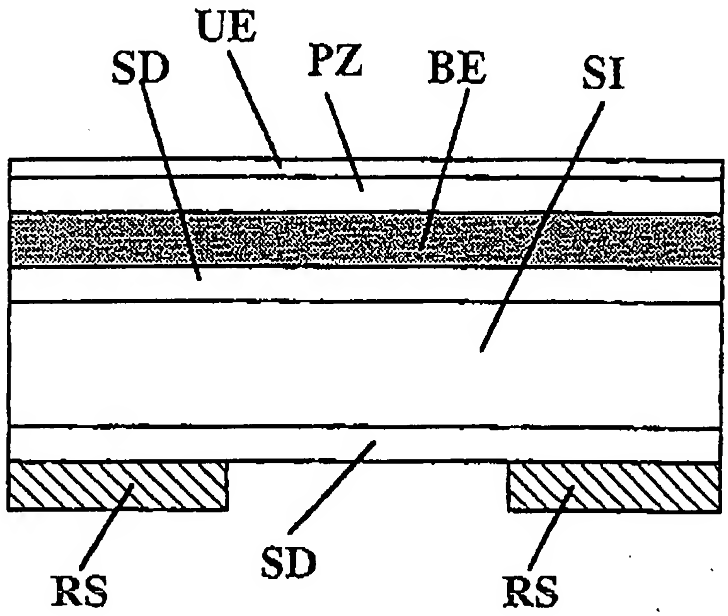

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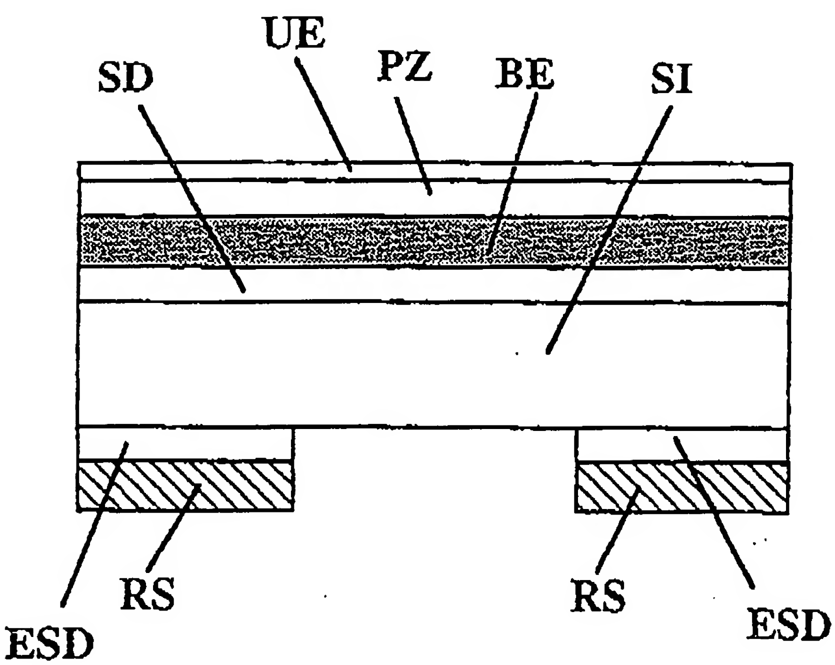

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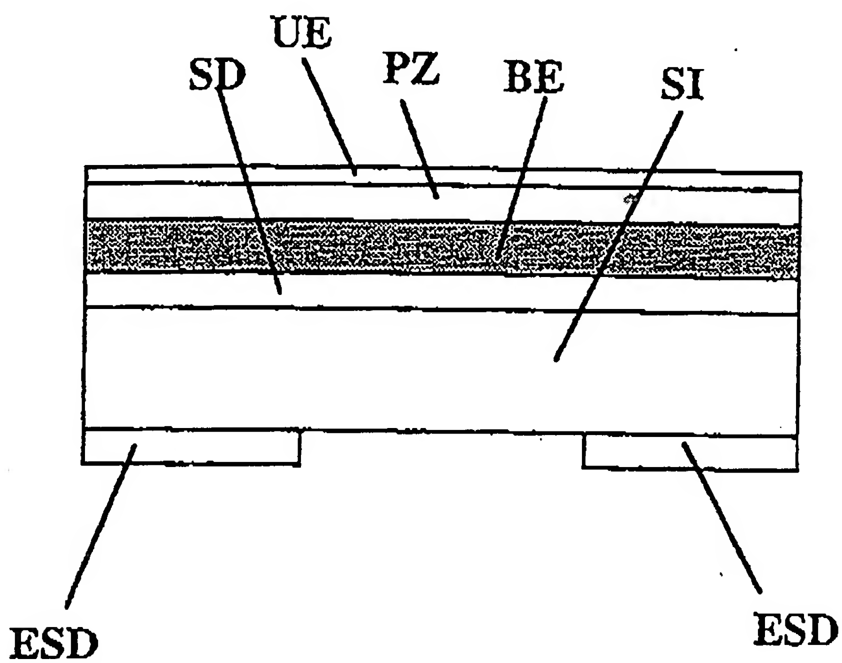

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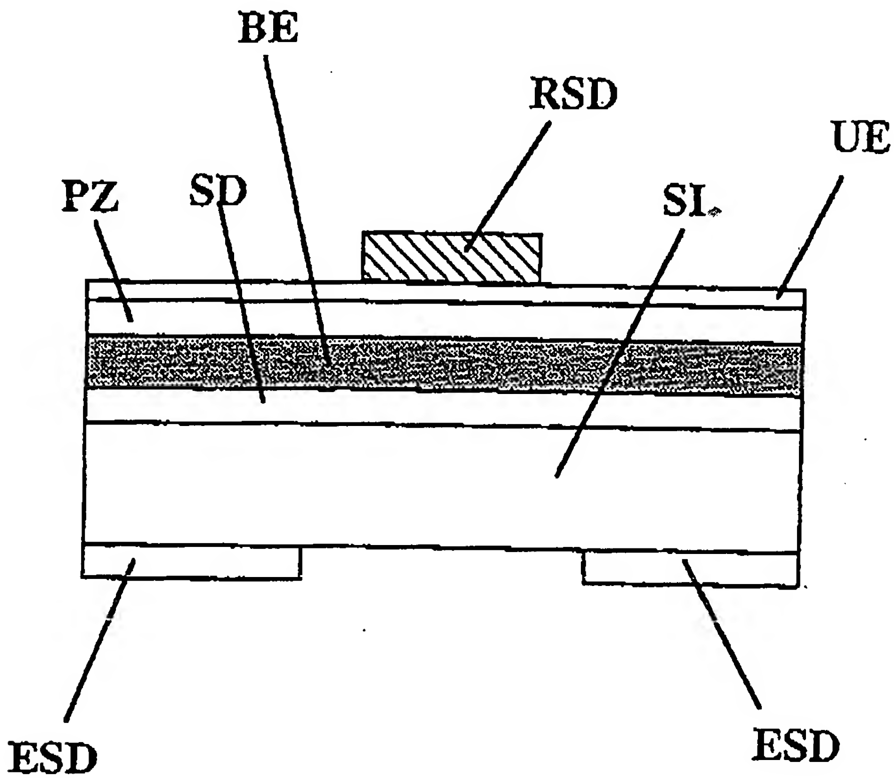

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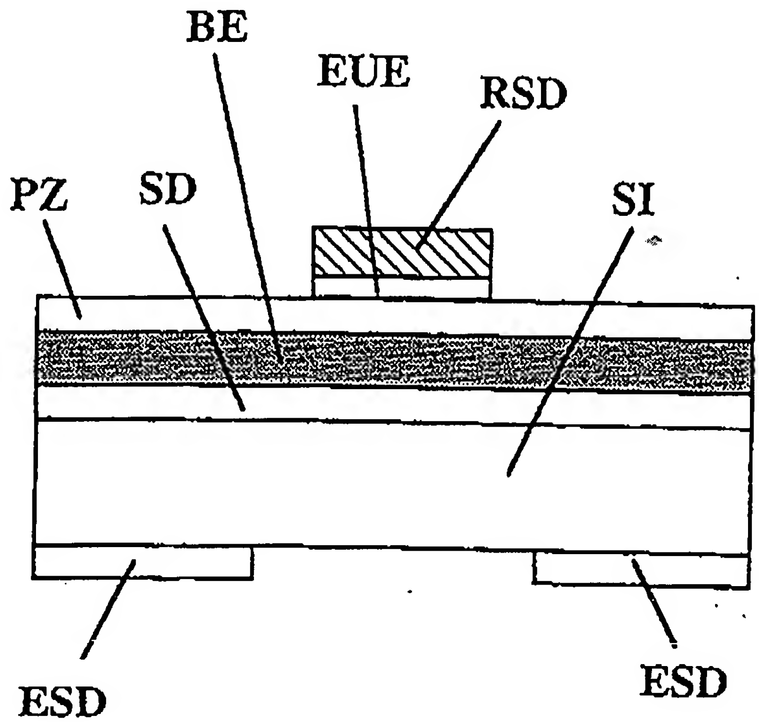

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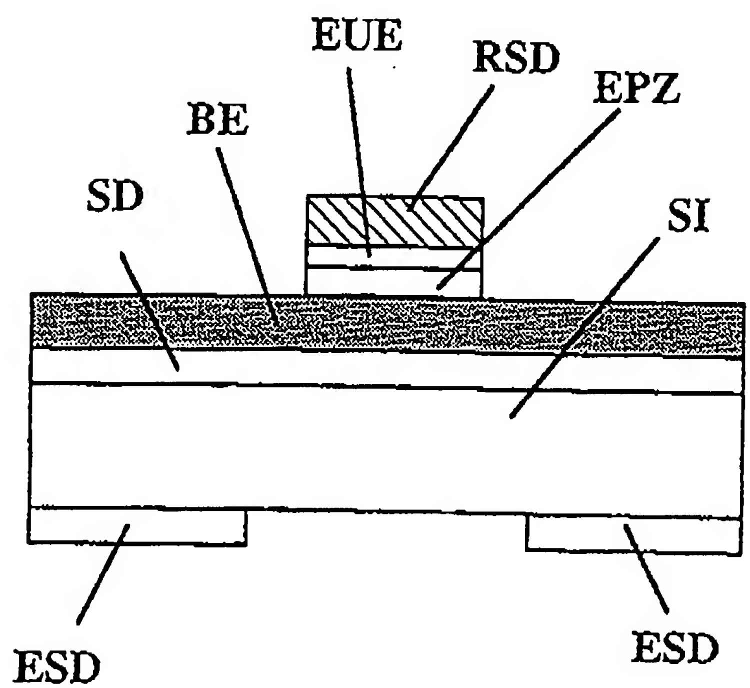

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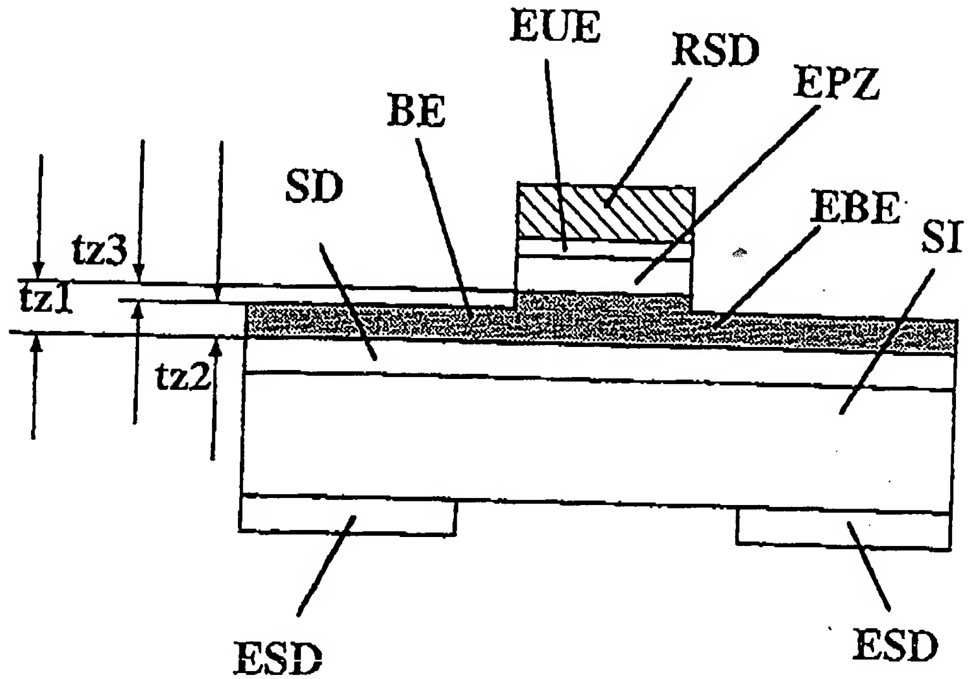
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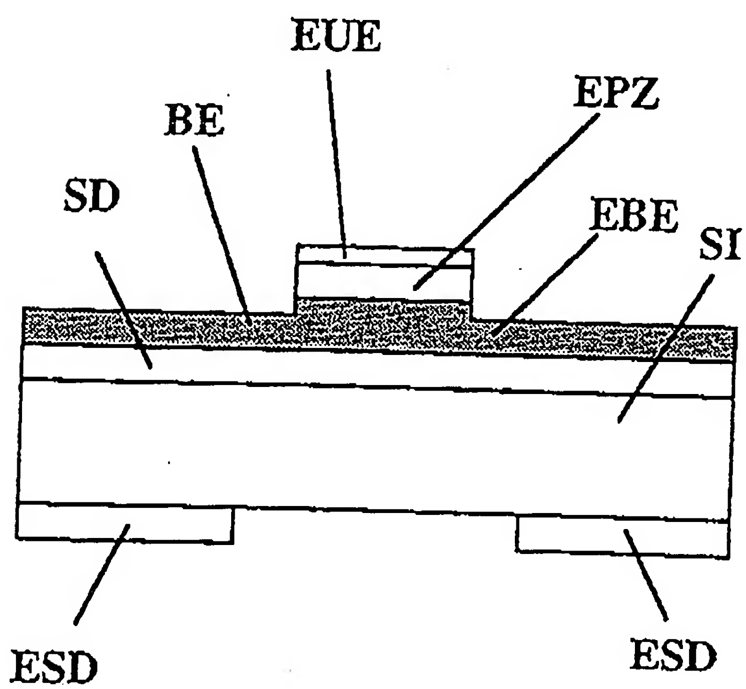
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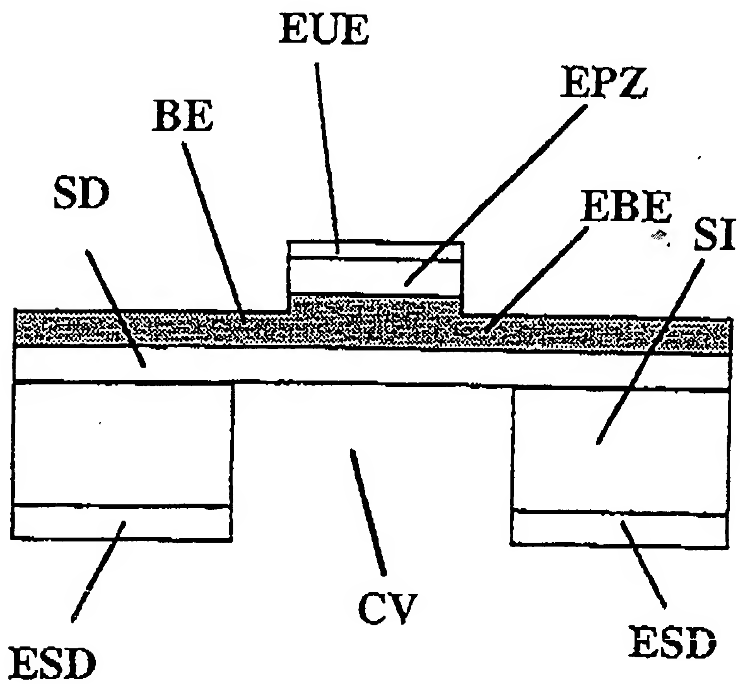
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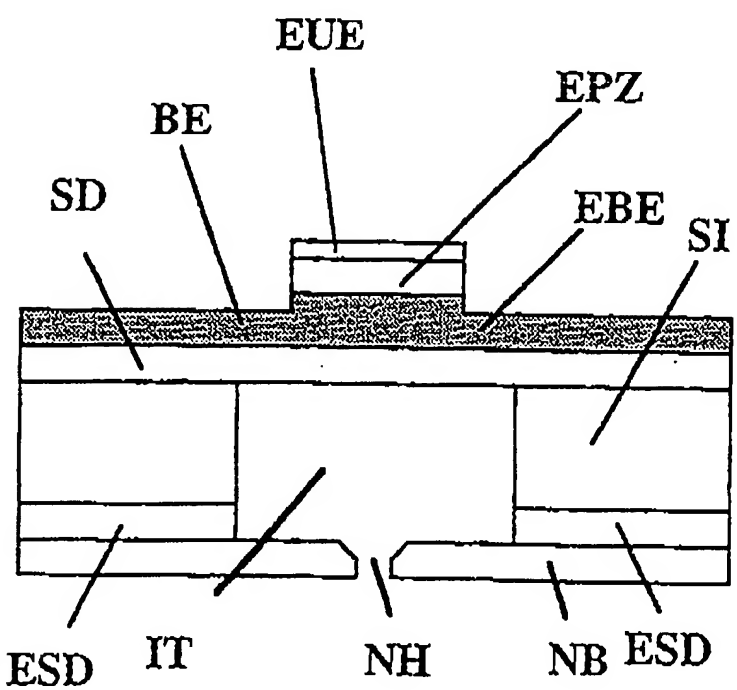
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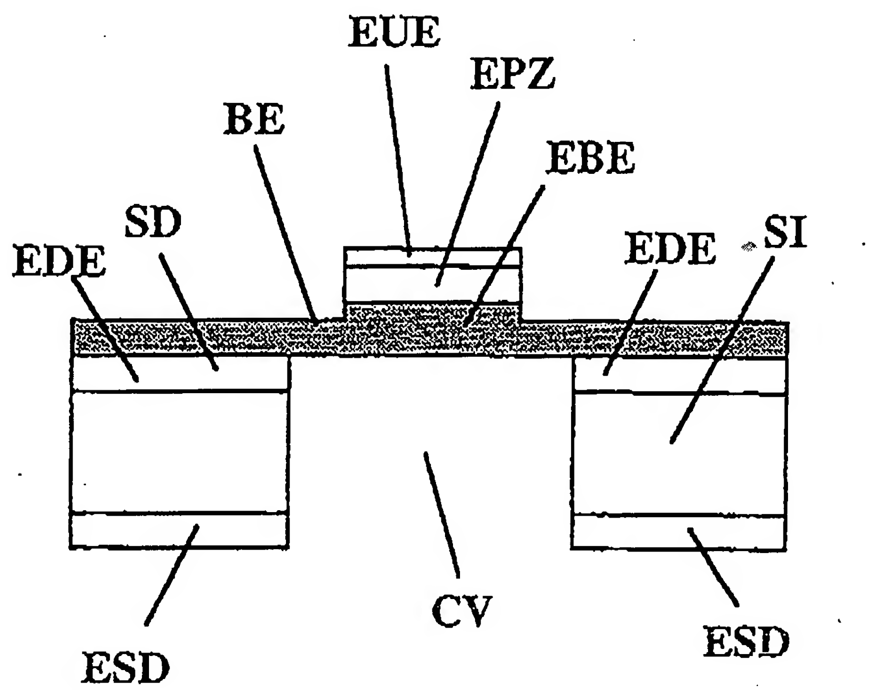
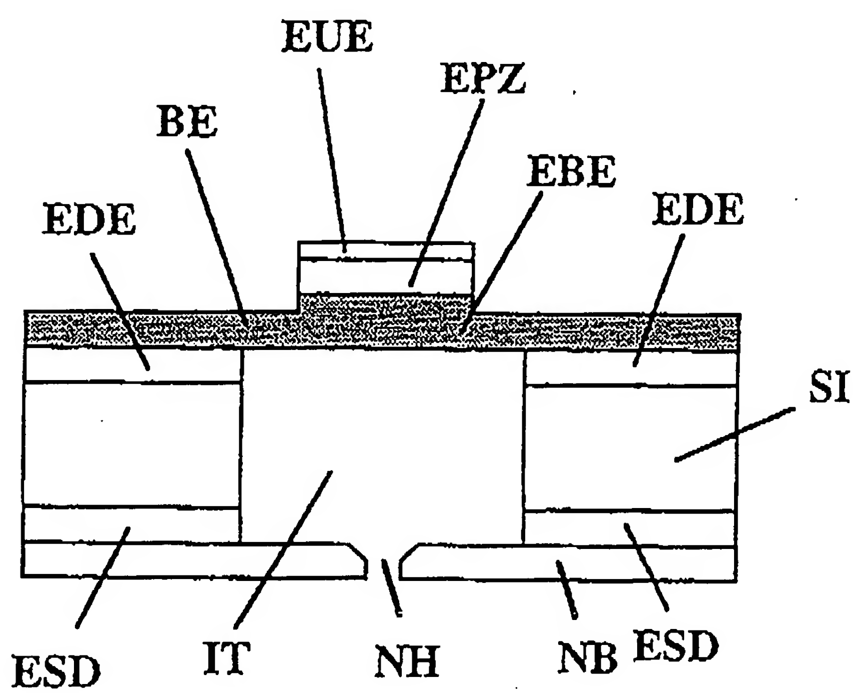
ESD

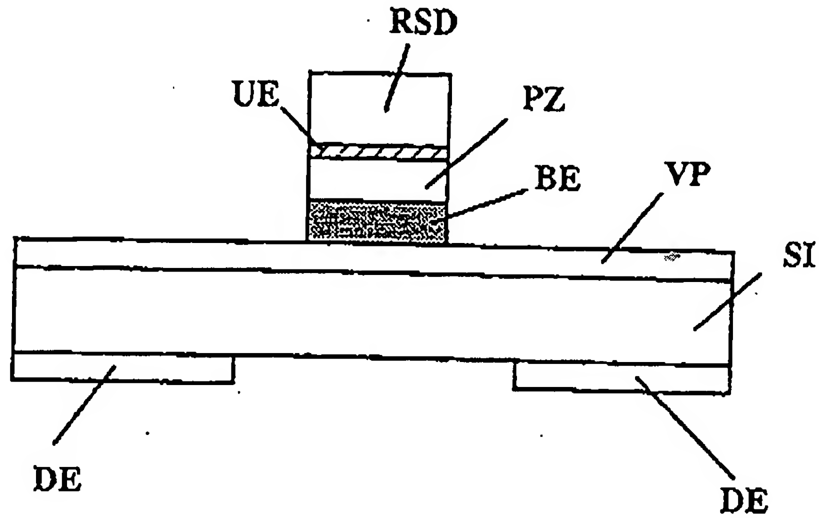
【図２０】


EUE
EPZ
BE
EBE
SD
EDE
EDE
SI
CV
ESD
ESD

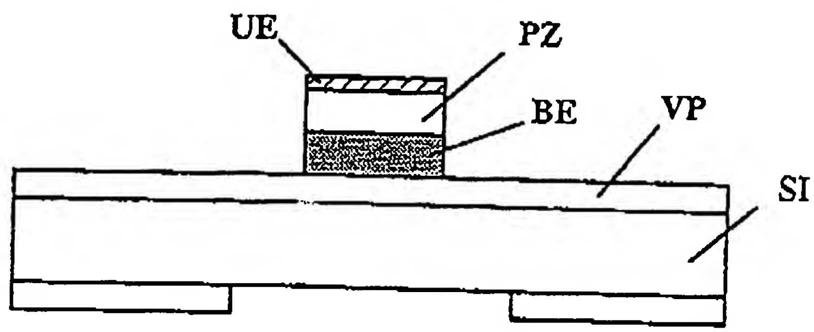
【図２１】


EUE
EPZ
BE
EBE
EDE
EDE
SI
ESD
IT
NH
NB
ESD

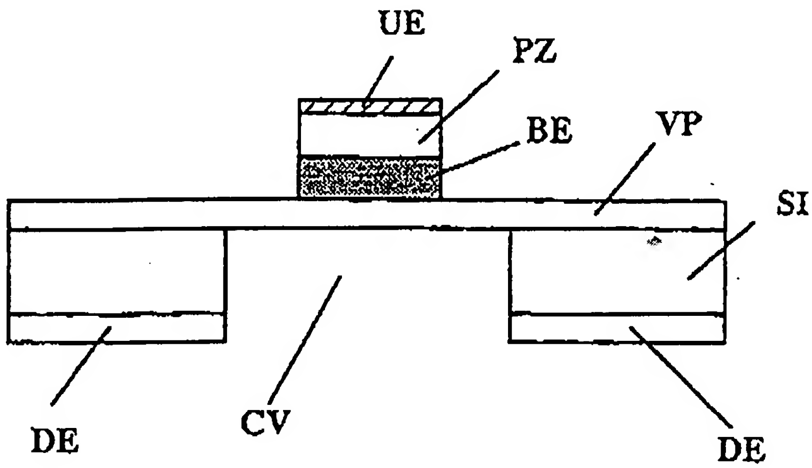
【図２２】



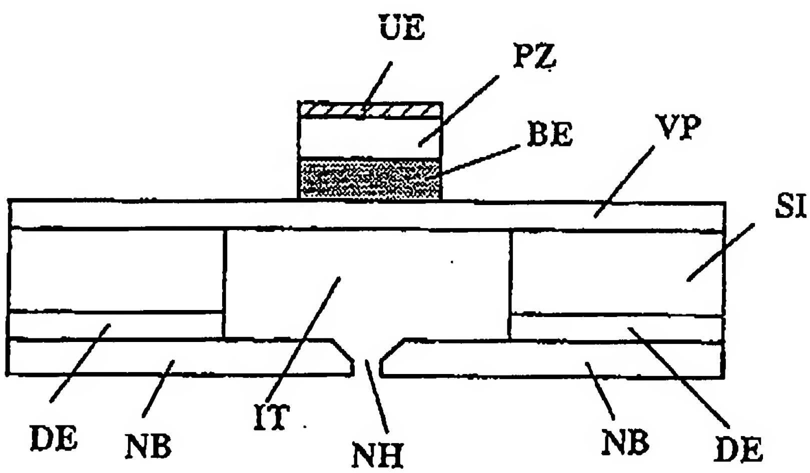
【図２３】



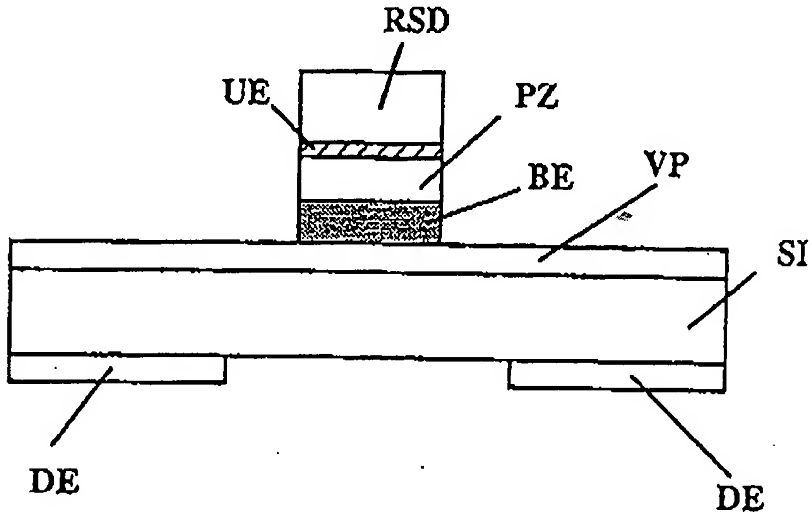
【図２４】



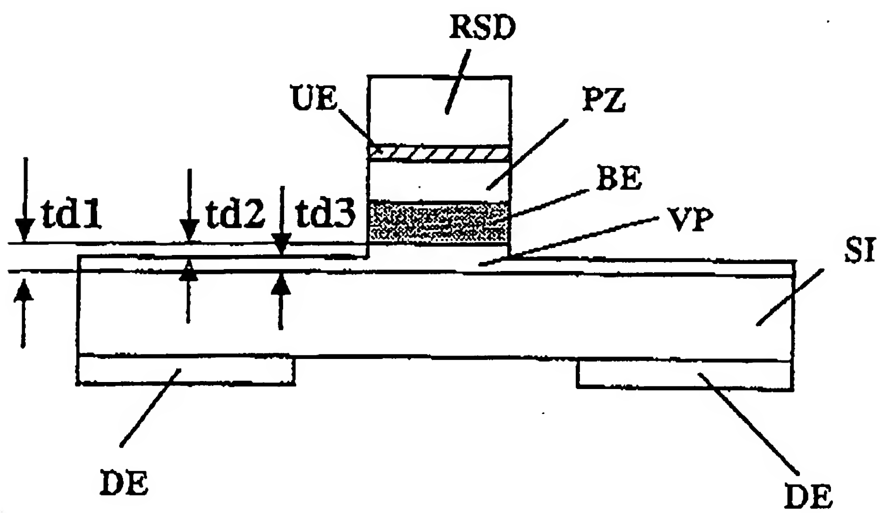
【図２５】



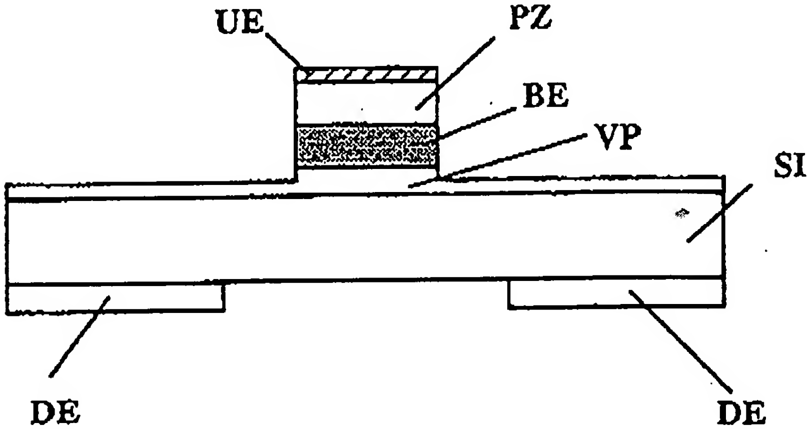
【図２６】



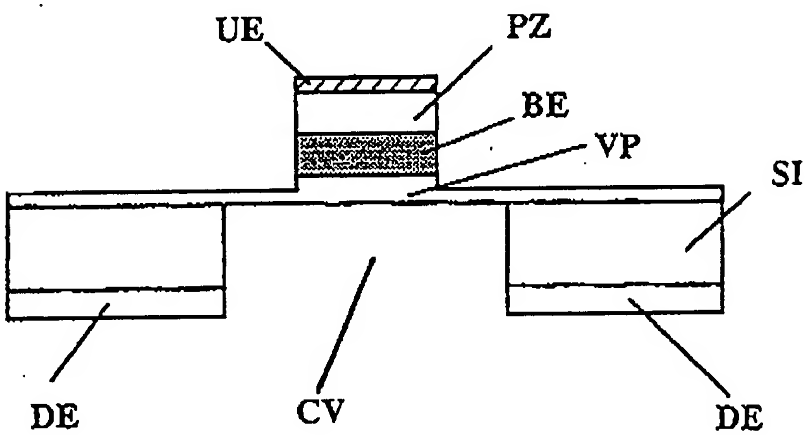
【図２７】



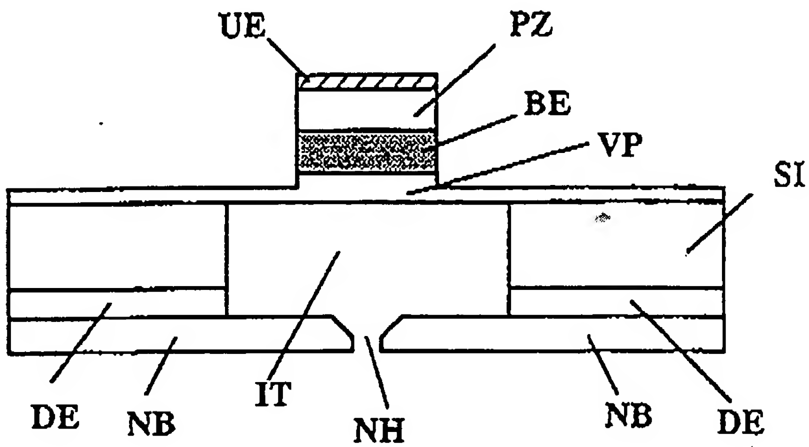
【図２８】



【図２９】



【図３０】



【図３１】